Scientists use Roadrunner supercomputer to unravel the mysteries of exploding stars

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Los Alamos, New Mexico, November 16, 2009 — Despite decades of research, understanding turbulence, the seemingly random motion of fluid flows, remains one of the major unsolved problems in physics.

“With the Roadrunner supercomputer, we can now look in detail at previously inaccessible flows,” said Daniel Livescu, of Laboratory’s Computational Physics and Methods group. Involving a technique known as Direct Numerical Simulations (DNS), researchers use the exact equations of fluid flow to calculate pressures, densities, and velocities, at very high resolution for both time and space, high enough to resolve the smallest eddies in the turbulent flow. This makes the DNS results as “real” as experimental data but requires immense computer power.

In many instances, these simulations are the only way turbulence properties such as those found in cosmic explosions like supernovae can be accurately probed. In these cases, turbulence is accompanied by additional phenomena such as exothermic reactions, shock waves, and radiation, which drastically increase the computational requirements.

Livescu and colleague Jamaludin Mohd-Yusof of the Laboratory’s Computational Physics and Methods group are using Roadrunner and a high performance Computational Fluid Dynamics code to perform the largest turbulent reacting flow simulations to date. The simulations consider the conditions encountered in the early stages of what is known as a “type Ia” supernova, which results from the explosion of a white dwarf star.

Type Ia supernovae have become a standard in cosmology due to their role in measuring the distances in the universe. Yet, how the explosion occurs is not fully understood. For example, the debate around the models that describe burn rate and explosion mechanics is still not settled. In addition, the flame speed — that is the rate of expansion of a flame front in a combustion reaction — is one of the biggest unknowns in current models.

“Solving the flow problem in a whole supernova is still very far in the future,” said Livescu, “but accurately solving the turbulent flow in a small domain around a single flame, characterizing the early stages of the supernova, has become possible. The very high resolution reacting turbulence simulations enabled by Roadrunner can probe parameter values close to the detonation regime, where the flame becomes supersonic, and explore for the first time the turbulence properties under such complex conditions.”

About Roadrunner, first to break the petaflop barrier

On Memorial Day, May 26, 2008, the “Roadrunner” supercomputer exceeded a sustained speed of 1 petaflop/s, or 1 million billion calculations per second. “Petaflop/s” is computer jargon—peta signifying the number 1 followed by 15 zeros (sometimes called a quadrillion) and flop/s meaning “floating point operation per second.” Shortly after that it was named the world’s fastest supercomputer by the TOP500 organization at the June 2008 International Supercomputing Conference in Dresden, Germany.

The Roadrunner supercomputer, developed by IBM in partnership with the Laboratory and the National Nuclear Security Administration, will be used to perform advanced physics and predictive simulations in a classified mode to assure the safety, security, and reliability of the U.S. nuclear deterrent. The system will be used by scientists at the NNSA’s Los Alamos, Sandia, and Lawrence Livermore national laboratories.

The secret to its record-breaking performance is a unique hybrid design. Each compute node in this cluster consists of two AMD Opteron™ dual-core processors plus four PowerXCell 8i™ processors used as computational accelerators. The accelerators used in Roadrunner are a special IBM-developed variant of the Cell processor used in the Sony PlayStation 3®. The node-attached Cell accelerators are what make Roadrunner different than typical clusters.

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